Palestine Polytechnic University
College of Engineering and Technology
Department of Mechanical Engineering
Mechanical Engineering Programs
ME 351 Machine Design I

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First Exam

Instructor: Dr. Momen Sughayyer — **Student Name:** Typical Solution
Date: March 31, 2013 — **Student Number:** .....
Time: 60 Minutes — **Section:** .....

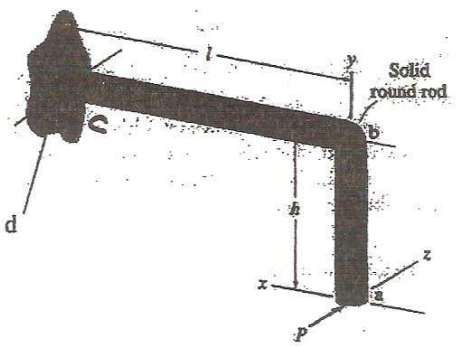
Notes to Students

- This exam is ***Open-Book Only***.
- You can start with any question and you should answer all the exam questions.
- Write all solutions in the space provided. No sheets should be added to the exam.

Grading System

Question	Q1 = 10 Pt	Q2 = 20 Pt	Q3 = 10 Pt	Total Grade = 40 Pt
Grade				

Q1) (*10 Points*) For the bracket shown in the figure, determine the deformation at point *a* in the direction of the force *P* using Castigliano's theorem, knowing that *P* is 200 lb, *L* is 15 in, *h* is 10 in, rod diameter *d* is 1 in, and the bracket is made of low-carbon steel.



→ member ab is subject to bending in yz-plane.

→ member bc is subject to bending in xz-plane, and to torsion about z-axis.

$\Rightarrow$ For ab $\Rightarrow$ $M_1 = Py$, $\frac{\partial M_1}{\partial P} = y$

$\Rightarrow$ For bc $\Rightarrow$ $M_2 = Px$, $\frac{\partial M_2}{\partial P} = x$

$T = Ph$, $\frac{\partial T}{\partial P} = h$

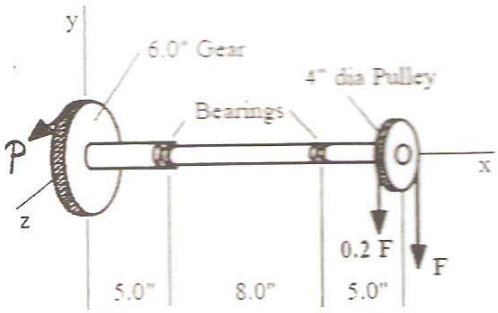
$$\Rightarrow \delta_a = \frac{\partial U}{\partial P} = \frac{1}{EI}\int_0^h Py(y)\,dy + \frac{1}{EI}\int_0^L Px(x)\,dx + \frac{1}{JG}\int_0^L Ph(h)\,dx$$

$$\delta_a = \frac{P}{EI}\left(\frac{y^3}{3}\right]_0^h + \frac{P}{EI}\left(\frac{x^3}{3}\right]_0^L + \frac{Ph^2}{JG}\left(x\right]_0^L$$

$$\delta_a = \frac{P}{3EI}\left(h^3 + L^3\right) + \frac{Ph^2L}{JG}$$

$\delta_a =$

(*20 Points*) For the shaft subjected to the forces shown in the figure, determine the allowable value for the force *F*. Include stress concentration, assume the factor of safety is to be 1.6 and the shaft is made from 4140 normalized steel.



All fillets are 1/32" radius

$\Sigma M_x = 0 = 3P + 2 \times 0.2F - 2F$

$P = 0.533F$

$T = 3P = 1.6F$

xy-plane:

$\Sigma M_B = 0 = 8C_y - 13 \times 1.2F \Rightarrow C_y = 1.95F$

$\Sigma F_y = 0 = -B_y + C_y - 1.2F \Rightarrow B_y = 0.75F$

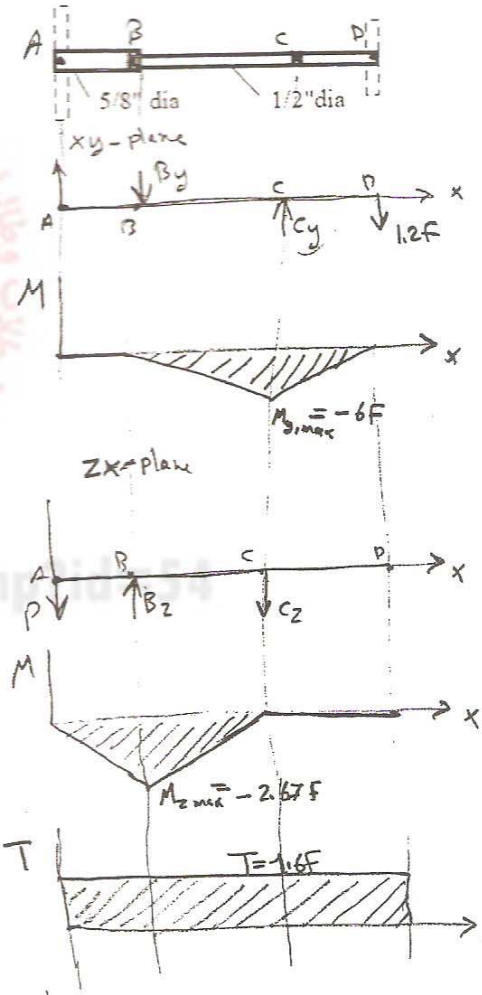
$M_{y,max} = 6F$

xz-plane:

$\Sigma M_C = 0 = 13P - 8B_z \Rightarrow B_z = 0.866F$

$\Sigma F_z = 0 = -P - C_z + B_z \Rightarrow C_z = 0.33F$

$M_{z,max} = 2.67F$



The max. bending moment is at C, but stress concentration is present at B, which means that both points must be check for stress:

at point C, no stress concentration:

$$\sigma_x = \frac{M_c}{I} = \frac{32M}{\pi d^3} = \frac{32(6F)}{\pi(0.5)^3} = 489F$$

$$\tau_{xy} = \frac{Tc}{J} = \frac{16T}{\pi d^3} = \frac{16(1.6F)}{\pi(0.5)^3} =$$

at point B, Stress concentration is present.

$$\sigma_x = K_t\left(\frac{32M}{\pi d^3}\right) =$$

$$\tau_{xy} = K_s\left(\frac{16M}{\pi d^3}\right) =$$

From tables

$K_t =$

$K_s =$

From tables

$S_y =$

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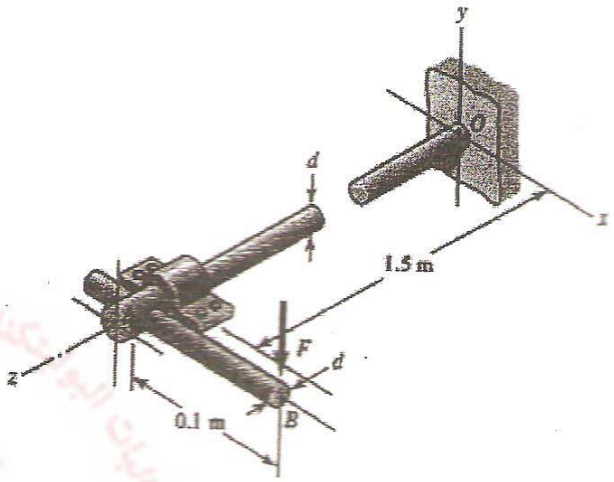
We calculate principal stresses or using the Mohr circle radius $\Rightarrow \tau_{max} = \sqrt{\left(\frac{\sigma_x}{2}\right)^2 + \tau_{xy}^2}$ for each case $\Rightarrow$ the higher value must be less than $\frac{S_y}{2n}$, $n = 1.6$

$$\tau_{max} < \frac{S_y}{\quad}$$

3) (*10 Points*) The figure illustrates a torsion-bar spring *OA* having a diameter d = 12 mm. The actuating cantilever *AB* also has d = 12 mm. Both parts are of carbon steel. Use superposition and find the spring rate k corresponding to a force F acting at *B*.



⇒ member OA is subject to twist only

$$\theta = \frac{TL}{JG}$$

$$T = 0.1F$$

$$J = \frac{\pi}{32}(0.012)^4$$

$$\theta = \frac{(0.1F)(1.5)}{\frac{\pi}{32}(0.012)^4(79.3)\times10^9} = 9.3\times10^{-4}F$$

⇒ Deflection due to θ at B ⇒

$$\delta_1 = \theta \times 0.1 = 9.3\times10^{-5}F\ m$$

⇒ member AB is subject to bending

$$\delta_2 = \frac{FL^3}{3EI} = \frac{F(0.1)^3}{3(207\times10^9)(\frac{\pi}{4}\times(0.012)^4)} = 1.6\times10^{-6}F$$

$$\Rightarrow \quad \delta_B = \delta_1 + \delta_2 = 9.3\times10^{-5}F + 1.6\times10^{-6}F$$

$$\delta_B = 9.46\times10^{-5}F\ m$$

$$F = K\delta_B \Rightarrow K = \frac{F}{\delta_B} = \frac{F}{9.46\times10^{-5}F}$$

$$K = \frac{1}{9.46\times10^{-5}} = 10.6\ KN/m$$

END OF EXAM – GOOD LUCK

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